PATENT SPECIFICATION

DRAWINGS ATTACHED

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893,051

Date of filing Complete Specification April 27, 1960.

Application Date April 30, 1959. *No. 14825/59.*

Complete Specification Published April 4, 1962.

Index at acceptance:—Class 41, A2(A1:B1:D), A9.

International Classification:—B01d.

COMPLETE SPECIFICATION

Improvements in or relating to an Electrodialysis Apparatus

We, JOHN THOMPSON-KENNICOTT LIMITED, a Company registered under the laws of Great Britain, of Ettingshall, Wolverhampton, in the County of Stafford, England, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to an electrodialysis apparatus.

A simple electrodialysis apparatus comprises a unit of three compartments arranged so that a centre compartment is divided from two outer compartments by permeable membranes. An electrode is placed in each of the outer compartments and the liquid to be processed is contained in or allowed to flow through the centre compartment. When one electrode is made positive and the other negative the ions of any ionisable compound contained in the liquid will migrate through the membranes, the positively charged ions towards the negative electrode and the negatively charged ions towards the positive electrode. The liquid contained in each electrode compartment becomes concentrated with ions of the appropriate charge and is replaced by fresh liquid either at intervals or by providing a continuous flow of liquid through the compartment. The liquid in the electrode compartment may be the same as or different from the liquid in the centre compartment. The liquid leaving the centre compartment is usually termed the diluate and that leaving the electrode compartments the concentrate.

In more recent processes use has been made of permeable ion discriminating membranes which prevent the respective ions, once they have passed through the membrane, from returning. These membranes have made possible the design and construction of a multiunit apparatus comprising a large number of compartments separated by selective membranes. Such an apparatus would comprise compartments divided from one another in the lengthwise direction by alternately disposed anion and cation selective membranes, the outermost compartments of the apparatus being respectively provided with an appropriate electrode. An anion selective membrane is a membrane which will allow only negatively charged ions to pass through it. A cation selective membrane is a membrane which will allow only positively charged ions to pass through it.

The liquid to be processed would be introduced into all the compartments at one end and would be withdrawn at the other end. The liquid withdrawn from alternate compartments would be respectively the diluate, and the concentrate.

In an electrodialysis apparatus such as any of those referred to above it is usual to feed the liquid into each compartment through a single inlet from a supply line running the length of a number of compartments. As the inlet is usually of smaller diameter than the width of the compartment, the flow of liquid is not uniformly spread over the whole width of the permeable membrane with the result that the apparatus does not operate at the efficiency of which it is capable.

It is an object of the present invention to provide an electrodialysis apparatus in which a distribution of liquid over each permeable membrane of high uniformity is attained.

According to the present invention an electrodialysis apparatus comprises two permeable membranes spaced apart by an annular separator to define a closed space, a gasket interposed between the separator and each membrane to form a fluid-tight seal therebetween, two bars secured to the separator and dividing said space into a

main sub-space between two auxiliary sub-spaces, at least two liquid flow passages each extending through the membranes, gaskets and separator and each in communication with a different one of the auxiliary sub-spaces, and tabs on the gaskets engaging the bars to space the membranes away therefrom and define paths for the flow of liquid from one sub-space to an adjacent sub-space.

Preferably each passage communicates with its associated auxiliary sub-space by means of a slot cut in the separator.

Advantageously a restriction is formed in the slot at its end adjacent the passage.

Ideally, a cover is provided over the slot and extends into contact with the adjacent bar.

Some embodiments of the invention will now be described by way of example, reference being made to the accompanying drawings in which:—

Fig. 1 is a perspective view with parts broken away of a compartment of an electrodialysis apparatus according to the invention,

Fig. 2 is a section on the line II—II of Fig. 1,

Fig. 3 is a fragmentary perspective view, to a larger scale, of one form of separator,

Fig. 4 is a fragmentary perspective view, in a larger scale, of another form of separator,

Fig. 5 is a fragmentary perspective view, to a larger scale, of a further form of separator.

Each compartment of a stack of electrodialysis units comprises two permeable membranes 1 spaced apart by a separator 2 with the interposition of sealing means 3 to provide a liquid tight seal therebetween.

The separator 2 is an annulus of rectangular cross section having a rectangular central space 4, the side walls 5 being of greater length than the end walls 6. A bar 7 extends between the side walls 5 of the separator 2 at a location closely adjacent each end wall 6. The bar 7 is of the same thickness as the remainder of the separator 2 and is formed integrally with the side walls 5 thereby dividing the central space into three sub-spaces 4*a*, 4*b* and 4*c*. The separator 2 may be formed from a synthetic material, for example, polyethylene, polyvinyl chloride, polystyrene, or laminated reinforced thermosetting resin ranging in thickness from about 0.050 inches to 0.125 inches. A pair of passages 8, 8^1, 9, 9^1 extend through each end wall 6 of the separator 2 to open into opposite faces thereof. One pair of diagonally opposed passages 8, 9 communicate with the adjacent end sub-space 4*b* and 4*c* respectively.

The sealing means 3 comprise gaskets of the same size and of similar shape to the separator 2 and have apertures corresponding in size and location with the passages 8, 8^1, 9, 9^1. The gaskets are not provided with portions corresponding with the bars 7 of the separator 2 but are formed with two or more tabs 10 extending inwardly from their end walls. The tabs 10 may be rectangular, curved or triangular in shape, the latter being preferred, and are of such length that they will extend completely across the corresponding bar 7 of the separator 2 when the gasket is placed in position. The gaskets may be formed from flexible synthetic material, for example, plasticized polyvinyl chloride or polyethylene, ranging in thickness from about 0.005 inches to about 0.020 inches.

When a compartment is assembled, that is with a permeable membrane 1 on each side of the separator 2 and a gasket 3 interposed between each membrane 1 and the separator 2, gaps are left between the bars 7 of the separator 2 and the membranes 1 which are equal in width to the thickness of the gasket. These gaps permit liquid introduced into an end sub-space 4*b*, 4*c* to flow over the bars 7 which thus act as weirs spreading the liquid over the whole width of the membranes 1 except for those parts contacted by the tabs 10. Since the width of these gaps is small in comparison with the width of the separator 2 good distribution of the liquid in the central sub-space 4*a* of the compartment is ensured.

As the membranes 1 are not self-supporting the central sub-space 4*a* of the compartment must be filled with a suitable material 11. The material 11 must be fairly open to allow liquid to flow over and past it, and preferably should cause flow of liquid to be turbulent so as to minimise polarisation. One such material is expanded polyvinyl chloride. If the final concentration required from a dilute compartment is very low, the central sub-space 4*a* can be filled with an ion exchange resin. Provided the particle size of the resin is greater than the thickness of the gasket the bar 7 will act as a retainer for the resin as well as a distributor for the liquid.

To produce a multiunit apparatus a number of compartments are arranged in side by side formation to constitute a stack with the passages 8, 8^1, 9, 9^1 registering so as to form conduits through which the liquid can be caused to flow. Usually the concentrate stream is caused to flow through one pair e.g. 8, 9 of diagonally opposite conduits and the dilute stream is caused to flow through the other pair e.g. 8^1, 9^1 of diagonally opposite conduits. The compartments are so disposed relative to each other that the liquid flowing in the conduits flows respectively into selected ones of the compartments of the stack. Normally the separators 2 of adjacent compartments are rotated

through 180° relative to each other so that concentrate is delivered to and diluate removed from alternate compartments. If it is desired to change the stream of liquid flowing in a compartment from say, the concentrate to diluate stream, the separator 2 is turned through 180° so that the passages previously registering with the conduits carrying the concentrate stream then register with the diluate stream.

It will be appreciated that by varying the thickness of the sealing means 3 the pressure of the liquid crossing the weir constituted by the bars 7 can be varied to the requisite value to give good distribution over the surface of the membrane 1 whatever the rate of flow of liquid in the passages 8, 8^1, 9, 9^1 or the dimensions of the separator 2.

In Figs. 1 and 2 the passages 8 and 9 communicate with their respective sub-spaces *4b*, *4c* by slots 12 and it has been found that if these slots 12 exceed a certain width the membrane 2 sags into them and permits leakage of liquid. To prevent this the slots 12 may be formed with a restriction 13 as shown in Fig. 3 or with a cover, which may be circular or rectangular as shown at 14 in Fig. 4, extending over the sub-space *4b* on to the bar 7. In this latter construction the tabs 10 on the sealing means 3 are arranged so that they do not coincide with covers 14. In another construction shown in Fig. 5, a bore 15 puts the passage 8 in communication with the sub-space *4b*. The bore 15 or the slots 12 may be plugged with a porous material for example, an expanded plactic material or sintered glass.

Figs. 3 and 4 show alternative forms of bar 7. In Fig. 3 the bar 7 is formed with a plurality of grooves 16 on each of its membrane contacting surfaces along which liquid can flow from the sub-space *4b* into the central sub-space *4a*. The grooves 16 may be of any desired cross-sectional shape and are of such a cross-sectional area that good distribution of liquid over the membrane surface is assured. In Fig. 4 holes 17 perform the function of the grooves 16 and may be of any desired cross-sectional shape and size. The holes 17 may be distributed over the bar 7 in a uniform fashion as shown or in a random fashion.

If the grooves 16 and holes 17 are of such a size that the material 11 filling the central space would pass through them a pad 18 of porous material is provided on the material 11 side of the bar 7 to act as a filter.

Instead of being provided with grooves 16 or holes 17, the bar 7 may itself be constituted by a liquid-permeable material, for example an expanded plastic or sintered glass, secured to the side walls 5 of the separator 2.

It will be appreciated that in the constructions of Figs. 3 and 4 the bar 7 may be made separately from the separator 2 and subsequently secured to the side walls 5 thereof, for examples by locating the ends of the bar 7 in slots formed in the side walls 5.

The separator 2 may be formed with a sealable inlet 19 (Fig. 5) through which filler material can be introduced into the central space *4a* when the separator 2 has been combined with the membranes (not shown) to form a compartment. The filler material is carried in a stream of air or as a thin slurry in water into an aperture 20, formed in a lug 21 integral with the separator 2, which communicates with the inlet 19. In the embodiment shown in Fig. 5, as in all previously described embodiments of this invention, communication between the sub-space *4b* and the main sub-space *4a* is afforded by way of gaps formed between the bar 7 and the membranes 1 (not shown in this figure), by the interposition of the gasket tabs 10 (not shown in this figure). Communication between the sub-space *4b* and the main sub-space *4a* of the embodiment shown in Fig. 5 may also be afforded by the formation of grooves 16 (as in Fig. 3) in the bar 7; or by the formation of holes 17 (as in Fig. 4) in the bar 7; or by making the bar 7 of a liquid-permeable material, as previously described.

Lugs 22 (Fig. 4) may be provided on one or both pairs of opposed walls of the separator 2 to provide means on which clamps can be engaged to hold the compartments tightly together as they are being assembled. By means of the lugs 22 a further compartment comprising membrane 1, sealing means 3, separator 2, sealing means 3, membrane 1, can be assembled on top of previously assembled compartments without the pressure holding the previously assembled compartments in sealing engagement being released. For this purpose a lug 21 may constitute a lug 22.

WHAT WE CLAIM IS:—

1. An electrodialysis apparatus comprising two permeable membranes spaced apart by an annular separator to define a closed space, a gasket interposed between the separator and each membrane to form a fluid-tight seal therebetween, two bars secured to the separator and dividing said space into a main sub-space between two auxiliary sub-spaces, at least two liquid flow passages each extending through the membranes, gaskets and separator and each in communication with a different one of the auxiliary sub-spaces, and tabs on the gaskets engaging the bars to space the membranes away therefrom and define paths for the flow of liquid from one sub-space to an adjacent sub-space.

2. An apparatus according to Claim 1, wherein each passage communicates with its

associated auxiliary sub-space by means of a slot cut in the separator.

3. An apparatus according to Claim 2, wherein a restriction is formed in the slot at its end adjacent the passage.

4. An apparatus according to Claim 2, wherein a cover is provided over the slot and extends into contact with the adjacent bar.

5. An apparatus according to Claim 1, wherein each passage communicates with its associated auxiliary sub-space by means of a bore formed in the separator.

6. An apparatus according to any one of Claims 2 to 5, wherein the communicating means is filled with a porous material.

7. An apparatus according to any one of Claims 1 to 6, wherein grooves are formed in the tab-contacting surfaces of the bars to provide additional liquid flow paths between adjacent sub-spaces.

8. An apparatus according to any one of Claims 1 to 6, wherein passages are formed in the bars to provide additional liquid flow paths between adjacent sub-spaces.

9. An apparatus according to any one of Claims 1 to 6, wherein the bars are formed of a liquid-permeable material.

10. An apparatus according to any one of the preceding claims, wherein the main sub-space contains a filler material.

11. An apparatus according to Claim 10, wherein the filler material is an ion exchange resin.

12. An apparatus according to Claim 10 or 11, wherein a sealable inlet is formed in a side wall of the separator to permit filler material to be introduced into the main sub-space.

13. An apparatus according to Claim 10, 11 or 12, wherein a pad of porous material is disposed on the main sub-space side of the bars to act as a filler.

14. An apparatus according to any one of the preceding claims, wherein lugs are provided on the separator to permit clamping means to be engaged thereon.

15. An electrodialysis apparatus substantially as herein described.

16. An electrodialysis apparatus substantially as herein described with reference to Figs. 1 and 2, and Fig. 3, 4 or 5 of the accompanying drawings.

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PROVISIONAL SPECIFICATION

Improvements in or relating to an Electrodialysis Apparatus

We, JOHN THOMPSON-KENNICOTT LIMITED, a Company registered under the laws of Great Britain, of Ettingshall, Wolverhampton, in the County of Stafford, England, do hereby declare this invention to be described in the following statement:—

The present invention relates to an electrodialysis apparatus.

A simple electrodialysis apparatus comprises a unit of three compartments arranged so that a centre compartment is divided from two outer compartments by permeable membranes. An electrode is placed in each of the outer compartments and the liquid to be processed is contained in or allowed to flow through the centre compartment. When one electrode is made positive and the other negative the ions of any ionisable compound contained in the liquid will migrate through the membranes, the positively charged ions towards the negative electrode and the negatively charged ions towards the positive electrode. The liquid contained in each electrode compartment becomes concentrated with ions of the appropriate charge and is replaced by fresh liquid either at intervals or by providing a continuous flow of liquid through the compartment. The liquid in the electrode compartment may be the same as or different from the liquid in the centre compartment. The liquid leaving the centre compartment is usually termed the diluate and that leaving the electrode compartments the concentrate.

In more recent processes use has been made of permeable ion discriminating membranes which prevent the respective ions, once they have passed through the membrane, from returning. These membranes have made possible the design and construction of a multiunit apparatus comprising a large number of compartments separated by selective membranes. Such an apparatus would comprise compartments divided from one another in the lengthwise direction by alternately disposed anion and cation selective membranes, the outermost compartments of the apparatus being respectively provided with an appropriate electrode. An anion selective membrane is a membrane which will allow only negatively charged ions to pass through it. A cation selective membrane is a membrane which will allow only positively charged ions to pass through it.

The liquid to be processed would be introduced into all the compartments at one end and would be withdrawn at the other end. The liquid withdrawn from alternate compartments would be respectively the diluate, and the concentrate.

In an electrodialysis apparatus such as any of those referred to above it is usual to feed the liquid into each compartment through a single inlet from a supply line running the length of a number of compartments. As the inlet is usually of smaller diameter than the width of the compartment, the flow of liquid is not uniformly spread over the whole width of the permeable membrane with the result that the apparatus does not operate at the efficiency at which it is capable.

It is an object of the present invention to provide an electrodialysis apparatus in which a distribution of liquid over each permeable membrane of high uniformity is attained.

According to the present invention an electrodialysis apparatus comprising two permeable membranes spaced apart by a separator to form a compartment, sealing means interposed between the separator and each membrane, at least two passages in the separator for conveying liquids, at least one of said passages being in communication with the interior of the compartment and means for directing liquid entering the compartment towards the permeable membranes.

Preferably the separator comprises an annular member, means dividing the space within said member into at least two sub-spaces; at least two passages extending axially through the member and at least one of said passages being in communication with a sub-space.

Advantageously the dividing means comprises a bar extending between opposed sides of the annular member and the sealing means spaces the permeable membranes away from the bar.

In a preferred form of the invention a number of said compartments are arranged in side by side formation to constitute a stack with the passages in register so as to form conduits and so disposed relative to each other that said conduits communicate respectively with selected ones of the compartments of the stack.

Some embodiments of the invention will now be described by way of example.

Each compartment of a stack of electrodialysis units comprises two permeable membranes spaced apart by a separator with the interposition of sealing means to provide a liquid tight seal therebetween.

The separator is an annulus of rectangular cross-section having a rectangular central space, the side walls which are of greater length than the end walls. A bar extends between the side walls of the separator at a location closely adjacent each end wall. The bar is of the same thickness as the remainder of the separator and is formed integrally with the side walls thereby dividing the central space into three sub-spaces. The separator may be formed from a synthetic material, for example, polyethylene, polyvinyl chloride or polystyrene, ranging in thickness from about 0.040 inches to 0.125 inches. Two pairs of passages extend axially one pair through each end wall of the separator to open into opposite faces thereof. One pair of diagonally opposed passages communicate with the adjacent end sub-space.

The sealing means comprise gaskets of the same size and of similar shape to the separator and have apertures corresponding in size and location with the passages. The gaskets are not provided with portions corresponding with the bars of the separator but are formed with two or more lugs extending inwardly from their end walls. The lugs may be rectangular, curved or triangular in shape; the latter being preferred, and are of such length that they will extend completely across the corresponding bar of the separator when the gasket is placed in position. The gaskets may be formed from flexible synthetic material, for example, plasticised polyvinyl chloride or polyethylene, ranging in thickness from about 0.005 inches to about 0.020 inches.

When a compartment is assembled, that is with a permeable membrane on each side of the separator and a gasket interposed between each membrane and the separator, gaps are left between the bars of the separator and the membranes which are equal in width to the thickness of the gasket. These gaps permit liquid introduced into an end sub-space to flow over the bars which thus act as weirs spreading the liquid over, the whole width of the membranes except for those parts contacted by the lugs. Since the width of these gaps is small in comparison with the width of the separator good distribution of the liquid in the compartment is ensured.

As the membranes are not self-supporting the central sub-space of the compartment must be filled with a suitable material. The material must be fairly open to allow liquid to flow over and past it, and preferably should cause flow of liquid to be turbulent so as to minimise polarisation. One such material is expanded polyvinyl chloride. If the final concentration required from a dilute compartment is very low, the central sub-space can be filled with an ion exchange resin. Provided the particle size of the resin is greater than the thickness of the gasket the separator will act as a retainer for the resin as well as a distributor for the liquid.

To produce a multiunit apparatus a number of compartments are arranged in side by side formation to constitute a stack with the passages registering so as to form conduits through which the liquid can be caused

to flow. Usually the concentrate stream is caused to flow through one pair of diagonally opposite conduits and the diluate stream is caused to flow through the other pair of diagonally opposite conduits. The compartments are so disposed relative to each other that the liquid flowing in the conduits flows respectively into selected ones of the compartments of the stack. Normally the separators of adjacent compartments are rotated through 180° relative to each other so that concentrate is delivered to and diluate removed from alternate compartments. If it is desired to change the stream of liquid flowing in a compartment from say, the concentrate to diluate stream, the separator is turned through 180° so that the passages previously registering with the conduits carrying the concentrate stream then register with the diluate stream.

It will be appreciated that by varying the thickness of the gasket the pressure of the liquid crossing the weir can be varied to the requisite value to give good distribution over the surface of the membrane whatever the rate of flow of liquid in the passages or the dimensions of the separator.

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Leamington Spa: Printed for Her Majesty's Stationery Office by the Courier Press.—1962.
Published at The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtained.

Fig. 1.

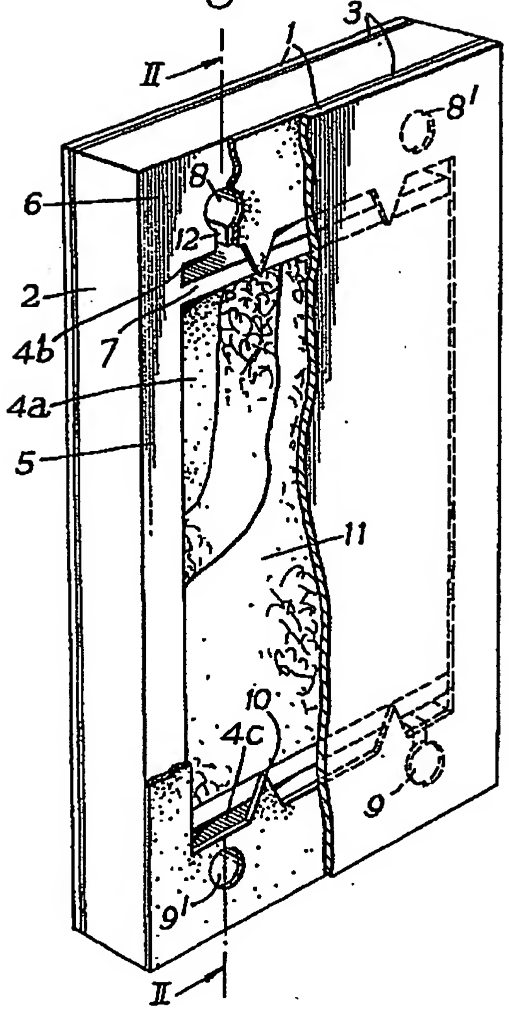
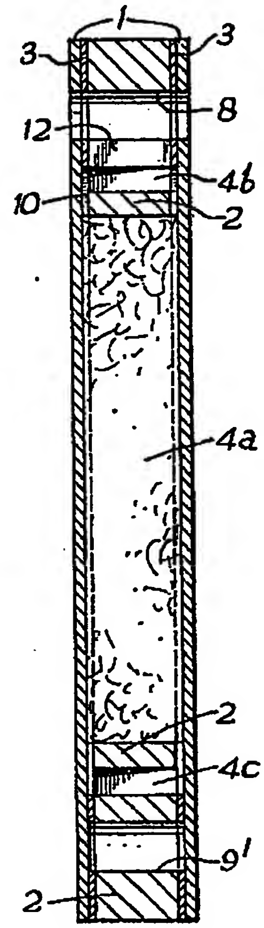


Fig. 2.



893,051 COMPLETE SPECIFICATION
2 SHEETS

This drawing is a reproduction of the Original on a reduced scale.
SHEETS 1 & 2

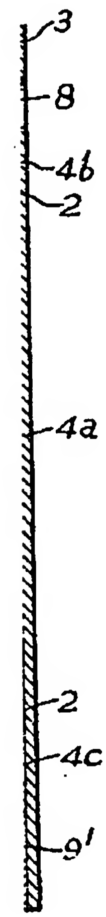


Fig.3

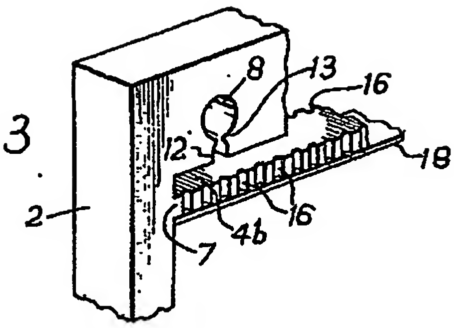


Fig.4.

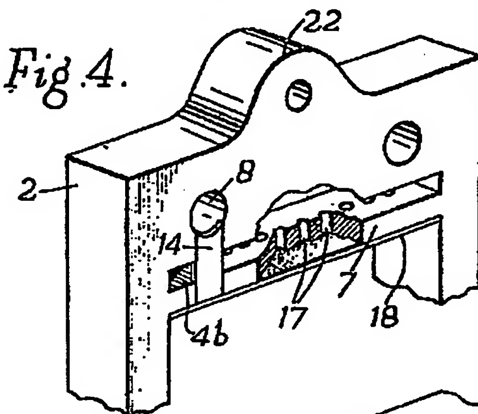


Fig.5.

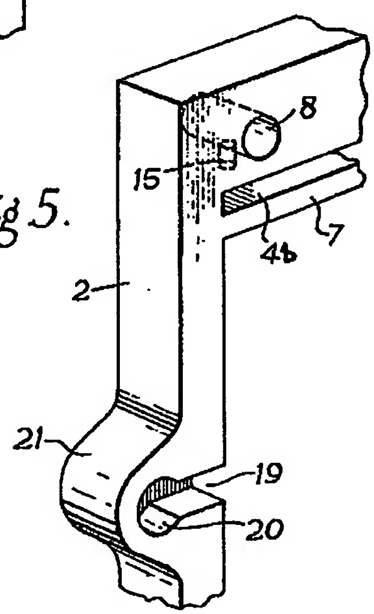


Fig. 1.

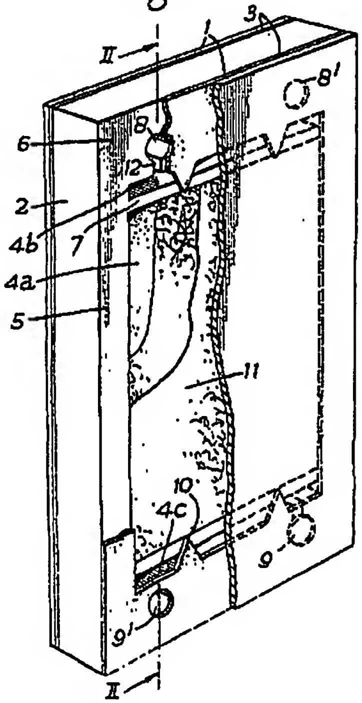


Fig. 2.

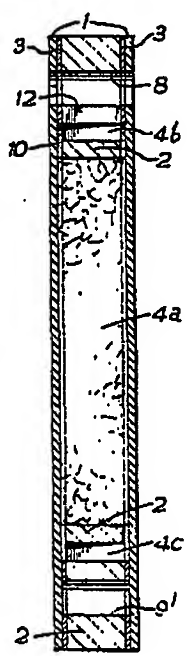


Fig. 3

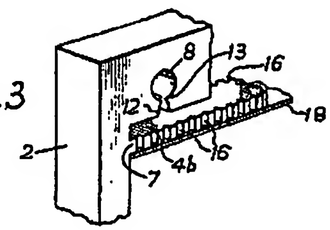


Fig. 4.

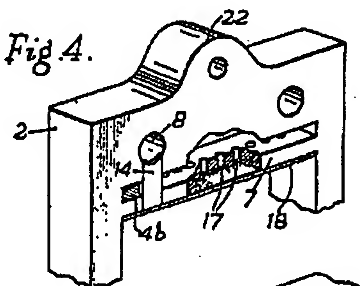


Fig. 5.